BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B70 11058

SUBJECT: An Improvement to the Skylab On-Board NC1 Targeting Routine - Case 610

DATE: November 30, 1970

FROM: R. C. Purkey

ABSTRACT

The launch times for the SL-3 Skylab mission may result in a time in coelliptic orbit which is beyond the desired limits of 30 to 75 minutes. In order to keep the coelliptic orbit time within this range, it is necessary to add an additional half orbit to the rendezvous profile between the NC1 and NC2 maneuvers. With this extra half orbit between NC1 and NC2, the approved on-board targeting routine exhibits extremely slow convergence for the NC1 maneuver. This memorandum suggests a minor addition to the on-board targeting routine which will correct this behavior.

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MEMORANDUM FOR FILE

Introduction

The on-board targeting routine for the NC1 and NC2 Skylab rendezvous maneuvers which was approved by the CSM Software Control Board, works very well for the standard Skylab rendezvous. This standard profile, shown in Figure 1, has an odd number of half orbits between NC1 and NC2. However, on the SL-3 mission, it may be necessary to add an additional half orbit to the profile between the NC1 and NC2 maneuvers in order to obtain the desired amount of time in coelliptic orbit. The approved targeting routine exhibits extremely slow convergence for the NC1 maneuver in this case.* Some minor changes are suggested in this memorandum which will correct this behavior.

The Problems

The standard Skylab profile restricts CSM launches to occur between approximately 06:30 and 18:30 EST, if the time in coelliptic orbit is constrained to be between 30 and 75 minutes. The connection between launch time of day and time in coelliptic orbit arises from the fact that the TPI maneuver (which terminates the coelliptic phase) is performed near midnight of the orbit, while the NSR maneuver (which begins the coelliptic phase) is performed an even number of half orbits less 35° beyond the launch insertion point. A minimum time is desired in coelliptic orbit in order to allow sufficient time for on-board navigation and TPI maneuver preparation. The constraint on the maximum time in coelliptic orbit arises from the desire to limit the propagation of expected state errors following NSR so that the TPI state will be reasonably close to nominal. The 30 and 75 minute limits are not rigid but have generally been assumed.

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*Sample runs have indicated that the routine requires on the order of three times as many iterations for this case -- resulting in iteration counts larger than the maximum allowed.

Figure 2 shows the time spent in coelliptic orbit on the standard profile for various combinations of launch day and time. The shaded area indicates the launches when the time in coelliptic orbit is either too long or too short.

The currently discussed mission, starting with the SL-1 launch on November 9, 1972 at 09:30 EST has the manned launches as follows:

SL-2	November 10	(day 1)	09:00 EST
SL-3	January 19	(day 71)	05:15 EST
SL-4	May 1	(day 173)	12:25 EST.

These are plotted in Figure 2 and it can be seen that SL-3 falls in the shaded area. Further, if a six-day launch window is allowed for SL-3 in order to guarantee a short rendezvous, SL-3 launch could occur as early as 03:15 EST on day 76.

In order to meet the limits on time in coelliptic orbit, and launch at a time within the shaded area of Figure 2, it is necessary to add an extra half orbit to the rendezvous profile before the NSR maneuver. This extra half orbit is best added between NC1 and NC2 as illustrated in Figure 3. This minimizes changes to the rendezvous procedures and leaves such items as on-board navigation schedules unperturbed. Inserting the extra half-orbit between insertion and the NC1 maneuver would result in an 81 nm post NC1 perigee altitude -- too low for the number of revolutions that can be spent in the NC1 to NC2 orbit.

This additional half orbit between NC1 and NC2 causes the targeting computations for the NC1 maneuver to be very slow in converging. This slow convergence is caused by two factors. First, the initial estimate for the NC2* maneuver assumes an odd number of half orbits between NC1 and NC2.

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*The NC1 targeting actually uses a dummy NH maneuver at the NC2 maneuver point and a dummy NSR maneuver at the NCC maneuver point. Dummy TPI target conditions are used by the routine when targeting the NC1 maneuver. In this way, an identical routine can be used to target both the NC1 and NC2 maneuvers.

Specifically, the routine uses the difference between the altitude at NC1 and the desired NCC altitude to compute the initial change required in the semi-major axis at NC2. This works well for the odd number of half orbits case but leads to a poor initial estimate for the even number of half orbits case. The other cause of the slow convergence is simply that no provision is made for the NC2 maneuver to be a function of the NC1 maneuver. For the odd number of half orbits case, the function of the NC2 maneuver is to simply raise the opposite side of the orbit from the NC1 altitude to the desired NCC altitude. Consequently, the required delta-v at NC2 is essentially independent of the NC1 delta-v. For the even number of half orbits case, however, the function of the NC2 maneuver is to raise the opposite side of the orbit from the altitude it has 180° after NC1 to the desired altitude at NCC. Hence, to a first order, the NC2 delta-v is linearly dependent on the NC1 delta-v. The approved routine ignores this relationship since it only considers the NCC altitude error it computed during the previous iteration to compute the NC2 delta-v required on the current iteration. In the even half-orbit case, the effect of the NC1 delta-v change will not be accounted for until one iteration later, when the NC1 delta-v will have changed again. This causes slow response and "chattering" in the convergence on the required NC2 delta-v.

Fixes

The approved routine may be modified to correct this situation in many ways. This section presents only a most obvious way to correct both the initial estimate of the NC2 maneuver and the iteration for the NC2 maneuver delta-v. Figure 4 shows the portion of the routine flow diagram affected by the proposed change. The added logic first checks the number of orbits between NC1 and NC2. If a whole number of orbits is not indicated, the routine simply skips the new logic. If a whole number of orbits is required, the logic then tests the iteration counter to determine if COUNT=0, indicating the first time through. If it is, a new initial estimate of the semi-major axis after NC2 is computed. This initial estimate of the post NC2 semi-major axis is computed from the apogee altitude of the NC1 to NC2 orbit and the desired altitude of NCC. This required semi-major axis is then used in the present logic to compute the maneuver required at NH. If the iteration counter (COUNT) is not indicating the initial iteration, the new logic corrects the required change in semi-major axis at NC2 by the change accomplished by NC1.

Specifically, the routine stores the semi-major axis that exists before the NC2 maneuver of each iteration. The correction, then, is the difference between the semi-major axis after NC1 for the current iteration and the semi-major axis from the previous iteration. After this correction is made, the present logic is followed to compute the NH maneuver.

This new logic has been tried in an engineering simulation and found to produce convergence in about the same number of iterations for either the even or the odd number of half orbit cases.

R. C. Purkey

1025-RCP-li

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Attachments

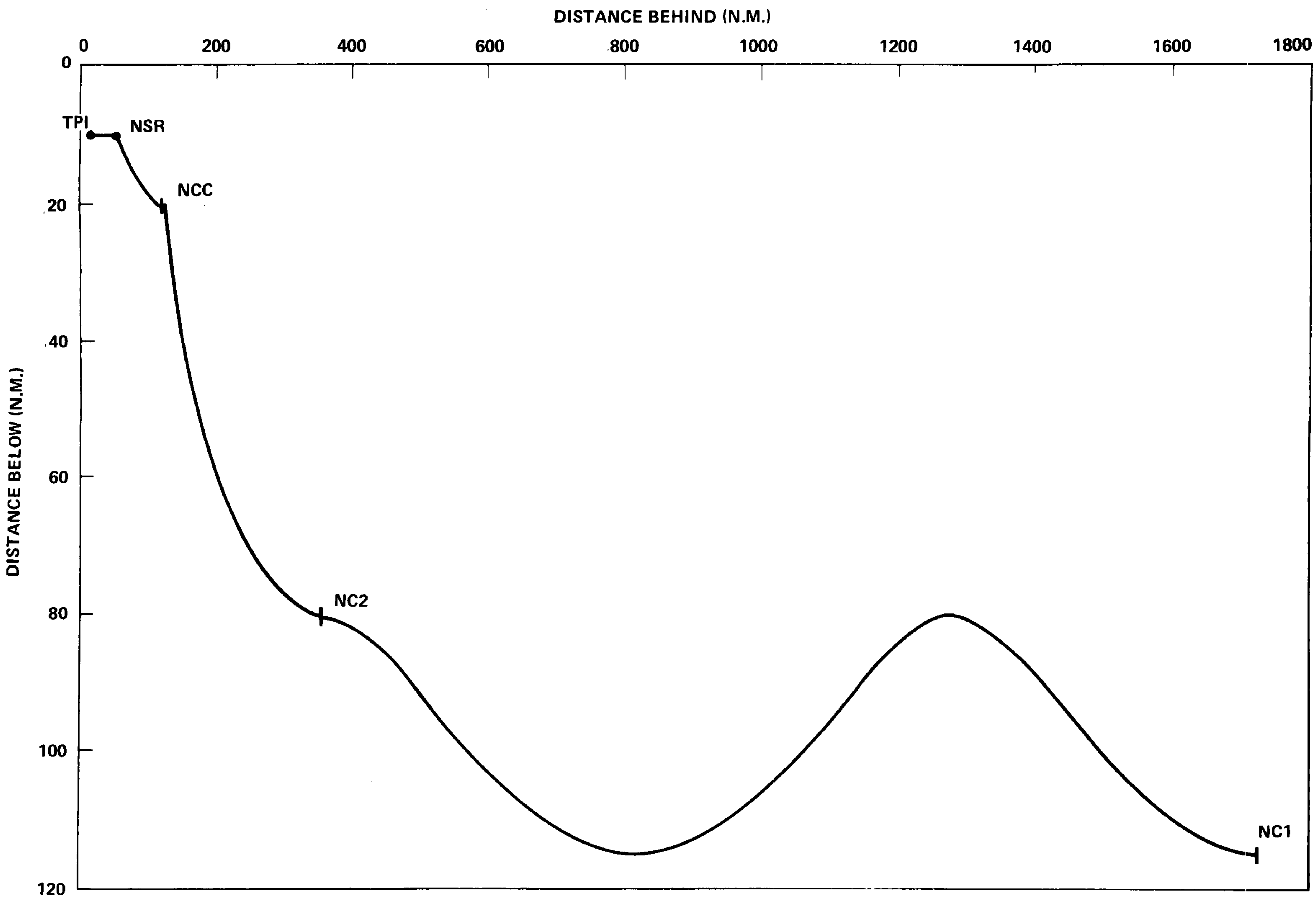

FIGURE 1 - THE STANDARD SKYLAB RENDEZVOUS PROFILE

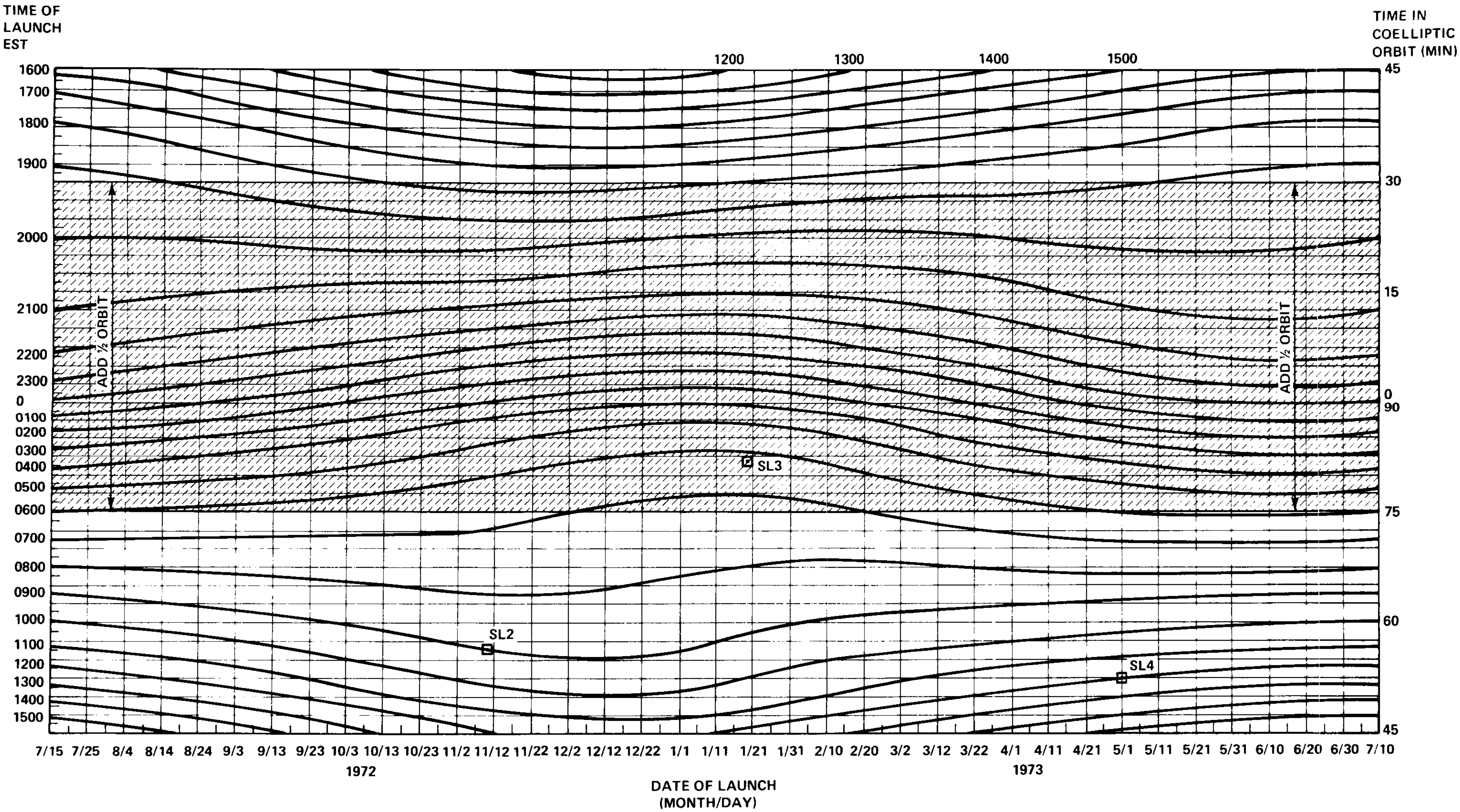

FIGURE 2 - TIME IN COELLIPTIC ORBIT VS DATE AND TIME OF LAUNCH

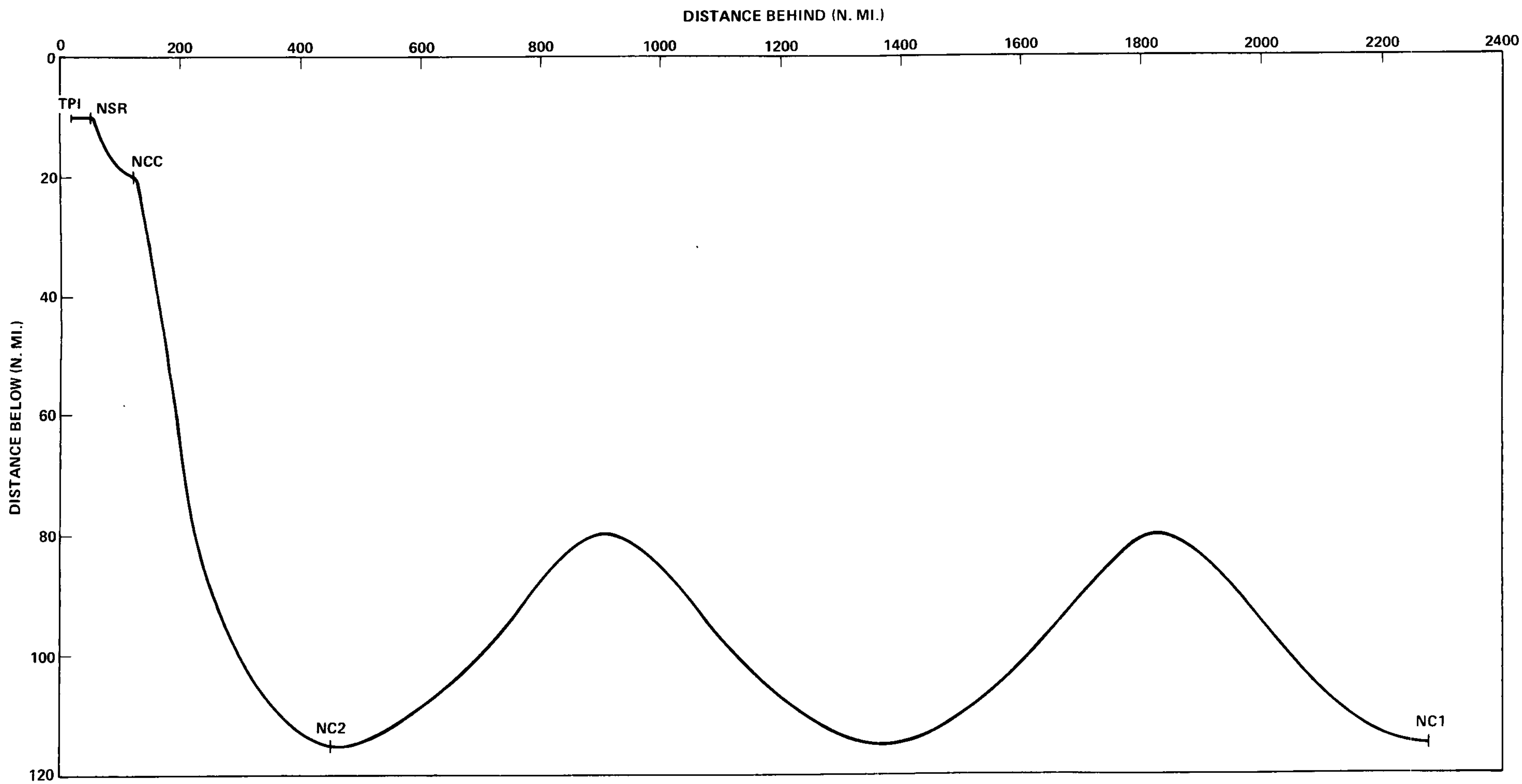

FIGURE 3 - PROPOSED ALTERNATE SKYLAB PROFILE

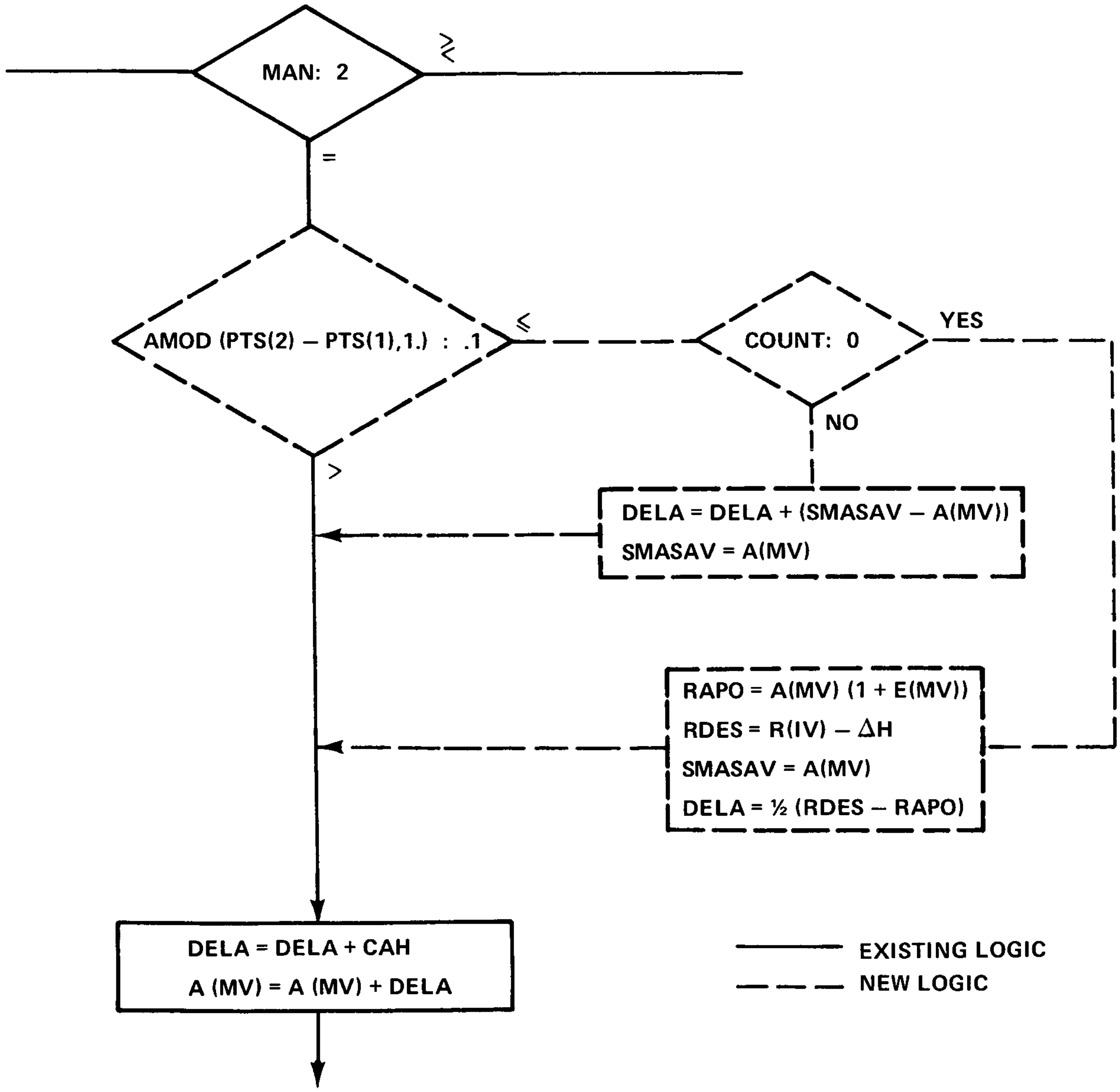

FIGURE 4 - PROPOSED CHANGE TO SUBROUTINE LOOP